Characterization of Seismoacoustic Properties of Marine Sediments

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LONG-TERM GOALS

The long-term goal of the research is to develop basic understanding of fundamental mechanisms affecting the seismoacoustic properties of marine sediments under various conditions. The research would lead to accurate modeling of the seafloor and reliable detection of buried objects.

OBJECTIVES

One objective of the research is to accurately measure the dispersion of high-frequency compressional waves in water-saturated sand important for subcritical penetration. Another objective is to study hidden capillary phenomena affecting grain to grain seismoacoustic wave coupling associated with bubbles in sediments, shear cavitation, crystallization in confined geometries, and solid-like behavior of an ultrathin seawater film trapped between two solid walls.

APPROACH

In high frequency acoustics, it is important to know the seismoacoustic properties of the seafloor top layer (few centimeters) controlling the interaction and conversion on underwater acoustic waves. The approach is to conduct precision laboratory experiments to characterize the dispersion of high-frequency compressional waves in water-saturated sand (fine, medium, coarse) and on 0.25 mm spherical glass beads provided by Prof. M. Buckingham (UCSD). The sound dispersion is determined by measuring the wavelength at different frequencies between about 70KHz-880 Khz. The phase velocity was accurately determined using a tone burst of a given frequency and counting an integer number of wave peaks passing by a time marker on the oscilloscope as the distance between source and receiver was varied. The distance between source and receiver was measured with an accuracy of 0.01 mm over a path length of 30 cm. During the measurements, a precision procedure was used to achieve the same level of sediment compactness. A repeatabilibty of one part in 1000 was achieved in the experiments.

Thin glass plates (Corning 0.13mm thick) were used to model capillary mechanisms on shear wave coupling between compressed sand grains with ruptured cavitations in the confined ultrathin water film. The Laplace-Young equation of capillarity used to predict the meniscus forces assumes the surface tension to be a constant. Van der Veen et al. [17] showed that when an ultrathin liquid film is confined in nanometer gaps between two solid surfaces, the liquid molecules become ordered giving rise to solid-like properties and causes the surfaces to stick. One point of interest is the instability of a confined ultrathin water layer in the presence of heterogeneous nucleation and cavitation in tension and shear. Microbubbles in seawater dissolve because the pressure inside the bubble is greater than the pressure in

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14. ABSTRACT
The long-term goal of the research is to develop basic understanding of fundamental mechanisms affecting the seismoacoustic properties of marine sediments under various conditions. The research would lead to accurate modeling of the seafloor and reliable detection of buried objects.

15. SUBJECT TERMS

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the water. The behavior of a shearing cavitation bubble confined between two plates in a microchannel is not known. Microbubbles trapped in ultrathin capillary channels cannot be removed by suction because the pressure exerted by capillary forces can far exceed one atmosphere. There are several mechanisms responsible for increasing the shear modulus of sand. Losert et al. [18] reported on gradual slow strengthening of wet sand under low pressure.

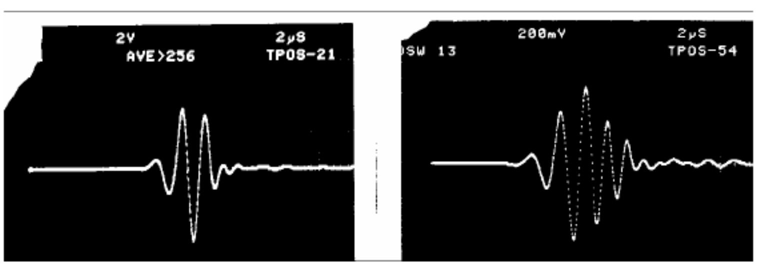
WORK COMPLETED

1. Identified mechanisms related to the adhesion of two solids with an ultrathin seawater layer. Conducted experiments investigating time dependent behavior, cavitation in shear, salt crystallization. normal and shear forces required to separate the shear coupled glass plates, and irreversible bonding as function of applied load. Obtained a series of photographs showing the hidden cavitation and crystallization events.

2. Completed dispersion measurements of high-frequency compressional waves in fine sand from Narragansett Beach, RI, coarse sand from Orchard Beach, Maine, play sand, and 0.25 mm diameter glass beads and came up with results contradiciting the existing theories as explained below.

RESULTS

Under the current ONR contract, controversial experimental results were obtained on the velocity of compressional waves in various saturated granular materials (fine sand, coarse sand, and glass beads provided by Prof. Buckingham). Contrary to all previously published theoretical and experimental results the measured velocity decreased as the frequency increased (90 KHz- 890 KHz). In coarse saturated sand, the compressional velocity <u>decreased</u> by 14 % , while the Biot-Stoll theory predicted an <u>increase</u> of about 1 %. The velocity in fine sand decreased by 3.6 %, and in the glass beads it decreased by 3%. Waveforms from fine sand are shown in Fig.1.



X = 8.000 cm X = 19.085 cm

Fig.1. Waveform of dispersed compressional wave in saturated fine sand (Narragansett Beach, RI) recorded at a distance X= 8.000 cm and X =19.085 cm.

The dispersion characteristic of the received waveform was independent of the water layer thickness above the sediment. Fig 2 shows the plotted experimental results. for the dispersion of high-frequency compressional waves in saturated fine sand (-x-) coarse sand (-□-), and glass beads (-o-). The dashed lines were obtained from linear regression. The author observed a similar dispersion in the low-frequency field results obtained by Chotiros [19] from the Kings Bay Experiment. The low-frequency field data by Chotiros [19] from the Kings Bay Experiment are replotted and displayed in

Fig. 2 showing a 5-6% decrease in the sound speed as the frequency was increased from 5 KHz to 60 KHz. measured at at two different grazing angles { θ = 90° (-diamond-), and θ =39° (-+-)}.

After obtaining the controversial findings, a brief communication [1] was distributed to colleagues in the field. The author received an input from Prof. Chotiros revealing a 1998 conference proceedings paper by Guillon et al. [20] having also reported on the sound speed decrease with increasing frequency in water-saturated sand. The author was not aware of Guillon's paper and is grateful to Prof. Chotiros for bringing it to his attention.. The dispersion results obtained under the current contract confirmed Guillon's results and were obtained from a different dispersion measurement method.

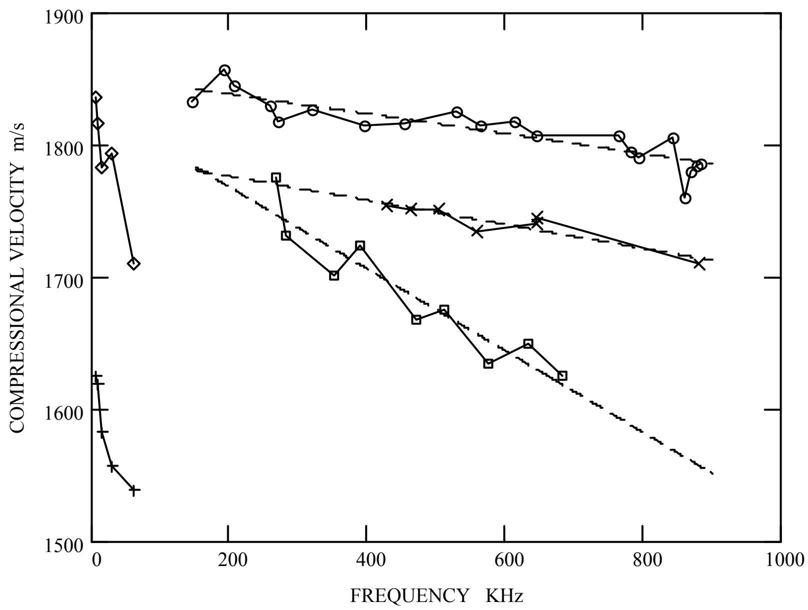


Fig. 2. Experimental data on the dispersion of compressional wave in saturated fine sand (-x-) coarse sand (-□-), and glass beads (-o-). Dashed lines obtained from linear regression. The author replotted the low-frequency field data by Chotiros [19] from the Kings Bay Experiment showing a decrease in the sound speed as function of frequency measured at different grazing angles { θ = 90° (-diamond-), and θ =39° (-+-)}.

IMPACT/APPLICATIONS

Develop fundamental physical understanding of mechanisms controlling the seismoacoustic properties of marine sediments leading to accurate acoustic modeling of littoral surficial layer and reliable detection of buried objects in shallow water and on the beach.

TRANSITIONS

The new findings will be summarized in the final contract report. A brief communication [1] was released to the research community on the observed inverse disperion of high-frequency compressional waves in water-saturated sand which contradicts the established theories. It is important to find the

answer to the fundamental question as to why the Biot theory failed to predict the observed high-frequency dispersion characteristic of sound in underwater sand.

RELATED PROJECTS

The work relates to several ONR projects on high-frequency acoustics by M. J. Buckingham (Scripps Institute of Oceanography:UCSD), N. P. Chotiros (ARL:UT), E.I. Thorsos/K.L. Williams/D. R. Jackson/D. Tang(APL:UW), M. Richardson/K. Briggs(NRL), T. Yamamoto(U. Miami), R. Stephen(Woods Hole Oceanographic Inst.), and H. J. Simpson/B. H. Houston(NRL)

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